Scale Measures within the Context of Dynamic Adjustment and External Economies

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Abstract: This study proposes an integrated approach to measuring the broader definition of scale economies proposed by Morrison and Siegel. The paper attempts to tackle the three unsolved problems in Morrison and Siegel, and thus will offer a methodological refinement and in the meantime make a significant contribution to the literature. Calculation of the total scale economies measures suggest Taiwan's production technology exhibit long-run increasing returns to scale in the presence of external economies. A comparison of the conventional measure of scale economies indicate a possible downward bias when short-run fixity as well as external economies from high-tech capital investment, R&E and human capital, are not explicitly recognized.

Keywords: total scale economies, dynamic adjustment, external economies

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1. Introduction

The continued growth of the postwar agriculture sector in most developing countries is constantly attributed to three general characteristics of supply: the advancement of production technology, the exploitation of scale economies, and the inducement of biased technical change. Consequently, a methodology that permits identifying the factors contributing to the growth as well as the structural change in production agriculture is desirable in explaining the differential patterns of agricultural growth. The key to the problem is, under what framework the change in technological characteristics, such as the rate and direction of technical change, scale economies, and determinants contributing to such changes, can be best captured by the observed change in quantities and prices.

In the endogenous growth literature, scale-augmenting variables such as human capital, R&D and high-tech capital investment have been used to examine the impact of accumulated knowledge capital on production efficiency. Although the empirical evidence supports significant improvement in efficiency from those external factors, the use of the production function to address issues of growth and capital return is quite limiting due to lack of flexibility in functional specification. Using a cost-based methodology, Morrison and Siegel (1997, 1998) proposed a broader definition of scale economies that is somewhat different from the conventional concept of scale economies. The "total scale economies", in Morrison and Siegel's terminology, is a combination of short-run fixity, long-run returns to scale, and external economies. Based on the total differentiation of the cost function with respect to output, the "total scale economies" identifies the different components driving the potential cost-output relationship.

Although Morrison and Siegel (1997, 1998) provide a rich specification of the magnitude and determinants of scale economies, there remain three problems unsolved -- the difficulty with the calculus of variations approach, the fact that most often time-series economic data are non-stationary, and the use of R&E expenditure to represent source of technological eternality may not be appropriate.

The first problem in Morrison and Siegel (1997, 1998) concerns the difficulty with the calculus of variations approach. Morrison and Siegel's approach is based on an explicit analytic solution to the Euler equation for the firm's intertemporal optimization problem. Due to the difficulty in solving the Euler equation, most often the approach is restricted to linear-quadratic technologies. Use of the dynamic dual approach will allow for a more general specification of the production technology. Based on the dynamic duality theory developed by Epstiein (1981) and McLaren and Cooper (1982), this paper develops the dynamic dual framework to measure the "total economies" proposed by Morrison and Siegel (1997, 1998).

The second problem comes from the fact that most often time-series economic data are non-stationary. The dependent variables may be well represented either by a trend stationary or a random walk process. When the data is trend stationary, a time trend can be used to capture technical change effects. However, when the data follows a random walk process, it is inappropriate to use a time trend to capture technical change effects. Therefore, before estimating the dynamic model, the time-series properties of the data need to be examined. To investigate the time-series properties of the data, this paper follows the four branch decision tree testing procedure used in Clark and Youngblood (1992).

The third problem is in terms of measuring the potential effect of agricultural research and extension (R&E). Morrison and Siegel use R&E expenditure to represent one source of technological eternality. Since external economies come from the notion of knowledge capital, which is a stock concept, whereas investment in R&E is a flow concept, it seems more appropriate to convert investment in R&E into R&E stock. To do so, the lag structure of R&E has to be specified and explicitly taken into account.

This paper tackles these three problems by developing a more general framework to measuring scale economies within the context of dynamic adjustment and external economies. Empirical implementation of the proposed scale measure is applied to the time-series data of Taiwan's production agriculture. Past studies on Taiwan's production agriculture focus on examining the substitution relationship between inputs and measuring the scale economies using the static approach. Most of the studies ignore the presence of external economies and fail to investigate the time-series properties of the data.

The remainder of the paper is organized as follows. The next section outlines the dynamic production model incorporating external economies and the procedures to derived the measure of scale economies. Empirical implementation and the discussion of results are presented in the following section. The last section gives the conclusion remarks.

The Dynamic Production Model Incorporating External Economies

To accommodate the spillover effects that arise from knowledge externalities, the dynamic production model is modified to explicitly incorporate a knowledge stock variable. The firm's production technology is described by the single-output production function $Y = F(X, K, \dot{K}, Z, t)$, which possesses all standard properties outlined in the neoclassical production theory. The production function is single valued, defining the maximum output obtainable from a specified set of inputs. It is a positive, continuous, twice-differentiable function with positive marginal product from variable inputs, $(X_1, X_2, \ldots, X_n)$, and from quasi-fixed inputs, $(K_1, K_2, \ldots, K_m)$. Technical change is considered as of the neutral type, therefore, the variable representing time, *t*, is included in the production function. The stock of knowledge is denoted by Z, additions to which is determined by the public research spending (*RE*), extension spending (*ES*), and agricultural education spending (*AE*).

The inclusion of net investment $\dot{K}$ in the production function reflects the internal cost associated with adjusting quasi-fixed factors in terms of foregone output. The adjustment cost is internal in the sense that expanding (contracting) the quasi-fixed factor stocks will result in a decrease (increase) in output. Therefore, the product of $\dot{K}$ and $F_{\dot{K}}$ is always negative. In addition, to assure the sluggish or gradual behavior in adjusting the levels of quasi-fixed factors, the diseconomies accompanying adjustment is assumed to be greater the faster the adjustment takes place. This assumption is equivalent to the convexity assumption of the adjustment cost function.

The firm producing with the production technology described above solves the dynamic optimization problem of the following form

$$J(p,w,c,k,z,t)=\max_{\dot{K}(t),X(t)}\int_0^{\infty}\left[pF(X(t),K(t),\dot{K}(t),Z(t),t)-w'X(t)-c'K(t)\right]e^{-rt}dt \qquad (1)$$

subject to $\dot{K}(t)=I(t)-\delta K(t),\ \ K(t)=k,$

$$\dot{Z}(s)=\begin{bmatrix} AE(s) \\ RE(s) \\ ES(s) \end{bmatrix},\ \ Z(t)=z$$

Here $J(.)$ is the value function representing the optimal value of problem (1) when the interior solution exists. The value function is the maximized sum of discounted profit flow over the entire planning horizon and can be viewed as the long-run profit function for the competitive firm. Let the stocks of the quasi-fixed factors and the knowledge component at the beginning of the period be denoted by *k* and *z*, respectively. The value function also depends on the price of output, *p*, price vector of variable inputs, *w*, and the rental price vector for the quasi-fixed factor stocks, *c*. All vectors are taken to be conformably defined. The constant discount and depreciation rates are denoted by *r* and δ, respectively.

As the firm expects prices denoting actual market values at time *t* to persist indefinitely, the dynamic optimization problem in (1) is transformed into a sequence of static optimization problems linked over time. The static optimization problem is expressed by the Hamilton-Jacobi equation

$$rJ(p,w,c,k,z)=\max_{\dot{K}(t),X(t)}\left\{pF(X(t),K(t),\dot{K}(t),Z(t),t)-\left[w'X(t)+c'k-(I(t)-\delta k)'J_k(\cdot)-\dot{Z}J_z\right]\right\} \qquad (2)$$

Epstein (1981) demonstrated that a full dynamic duality can be shown to exist between the value function and the production function, in the sense that each function is theoretically obtainable from the other by solving the appropriate static optimization problem as expressed in the Hamilton-Jacobi equation.

The first-order conditions characterizing the interior solution for the long-run profit maximization problem in (1) are

$$pF_{X_i}(X(t),K(t),\dot{K}(t),Z(t),t)=w_i\,, \qquad (3a)$$

$$-pF_{\dot{K}_j}(X(t), K(t), \dot{K}(t), Z(t), t) = J_{k_j}(.) \,. \tag{3b}$$

Based on the intertemporal optimization framework, the firm is assumed to operate in the short run but plan ahead to select a future short-run production situation (Stefanou, 1989). Therefore, condition (3a) is simply the dynamic analog of the cost-minimization condition in the static setting. Condition (3b) states that marginal cost of adjustment, $F_{\dot{K}_j}(.)$, must equal the negative of normalized shadow value of quasi-fixed factor stock. The shadow value of capital is normalized in the sense that the endogenously determined shadow value is divided by the price of output, that is, $J_{k_j}(.)/p$.

Employing the generalized version of Hotelling's Lemma (the dynamic Hotelling's Lemma), that is, by taking derivatives of equation (2) with respect to p, w and c, the output supply and input demand for both variable and quasi-fixed factors can be derived as:

$$Y^*(p,w,c,k,z,t) = rJ_p(.) - \dot{K}^*(.)J_{kp}(.) - \dot{Z}J_Z(.) \tag{4a}$$

$$\dot{K}^*(.) = J_{kc}^{-1}(.)[rJ_c(.) + k - \dot{Z}J(.)] \tag{4b}$$

$$X^*(.) = -rJ_w(.) + \dot{K}^*(.)J_{kw}(.) + \dot{Z}J_Z(.) \tag{4c}$$

To derive the scale measures for the dynamic production model incorporating scale economies, we can express the intertemporal profit maximization problem in (1) as the ratio of total revenue to total shadow cost. To see this, note that according to Stefanou (1989), the cost elasticity for the intertemporal cost minimization problem is defined as

$$\varepsilon = \frac{\partial \ln C}{\partial \ln Y} = \frac{LRMC}{LRAC}$$

where *C* denotes the long-run cost function for the single-output technology. To prove that *TSC*/*TR* equals the inverse of the cost elasticity, the intertemporal profit maximization problem is stated as a two-step profit maximization problem as follows:

$$J(p,w,c,k,z) = \max_{I(t),X(t)} \int_0^\infty \left[pF(X(t), K(t), \dot{K}(t), Z(t)) \right] e^{-rt} dt - S(w,c,k,y,z,t)$$

where $S(w,c,k,y,z,t)$ represents the long-run cost function. The optimization problem for the firm that seeks to minimize the discounted stream of costs is stated as follows:

$$S(w,c,k,y,z,t) = \underset{\dot{K}(\tau),X(\tau)}{\text{minimize}} \int_t^\infty e^{-r(\tau-t)}[W(\tau)'X(\tau) + C'(\tau)K(\tau)]dt,$$

subject to $\dot{K}(t) = I(t) - \delta\, K(t), \quad K(t) = k,$

$$\dot{Z}(s) = \begin{bmatrix} AE(s) \\ RE(s) \\ ES(s) \end{bmatrix}, \; Z(t) = z$$

The dynamic production model explicitly including nonstatic technology is expressed by appending $S_t(.)$ to the Hamilton-Jacobi equation of the following form,

$$rS(Y,w,c,k,z,t) = \underset{\dot{K}(t),X(t)}{\text{minimize}} \left\{ w'X + c'k + (I - \delta k)' S_k(.) + \dot{Z} S_z(.) \right\} + S_t(.)\,, \tag{2}$$

Alternatively, the right side of equation (2) may be interpreted as the sum of instantaneous costs of production, $w'X + c'k$, and the rate of variation of the value function, $\dfrac{dS(.)}{dt}$. That is,

$$rS(Y,w,c,k,z,t) = \underset{\dot{K}(t),X(t)}{\text{minimize}} \left\{ w'X + c'k + \frac{dS(.)}{dt} \right\}. \tag{3}$$

The alternative interpretation of (2) is developed by totally differentiating $S(Y, w, c, k, z, t)$ to yield

$$dS(.) = S_Y(.)dY + \sum_{i=1}^{n} S_{w_i}(.)dw_i + \sum_{i=1}^{m} S_{c_i}(.)dc_i + \sum_{i=1}^{m} S_{k_i}(.)dk_i + S_t(.)dt.$$

Assume that price expectations are static and output target remains unchanged at any given instant, we have

$$\frac{dS(.)}{dt} = (I - \delta k)' S_k(.) + \dot{Z} S_z(.) + S_t(.),$$

which states that the instantaneous variation of the long-run cost function, $dS(.)/dt$, involves three distinguished components. The first is the variation due to adjusting the capacity of the quasi-fixed inputs, $(I - \delta k)' S_k(.)$, the second is the variation associated with external economies, $\dot{Z}' S_z(.)$, and the third is the variation due to technological progress, $S_t(.)$.

3. Empirical Specification

Annual data for aggregate Taiwan agriculture over the period 1952 to 1987 is taken from Kuo (1991). All of the price and quality indices are constructed using the Tornqvist approximation to the Divisia index with 1986 as the base year. The data base consists of one output (the aggregate agriculture product) and four input groups (labor, intermediate input, capital, and land). The aggregate agricultural product is composed of two groups of products–crops and livestock. Crops consist of rice, corn, sorghum, beans, vegetables, fruits, and other field crops. Specifically, rice, fruits, and vegetables are the major crop productions in the country, comprising approximately 80 percent of the total value of crop production (Taiwan Economic Forecasts and Policy). The livestock group includes animal products and poultry. The major product in the livestock group is swine, which accounts for more than half of the total value of livestock production (Taiwan Economic Forecasts and Policy)

The four major inputs are labor, intermediate input, capital, and land. Agricultural land is measured by the area planted for the year. The labor input stands for number of workers in crop and livestock production. Capital includes numbers of animals used for production, long-term crops, farm durable equipment, and nonresidential structures. Intermediate inputs include fertilizer, pesticides, feed, seed, and other miscellaneous materials. The monetary data of both capital and intermediate inputs are deflated by the farm-paid price index.

The price of agricultural output is measured by the farm-received price index. Land rent stands for the rental price per hectare of agricultural land. The rental price for capital is calculated using the weighted average of rental costs. The price for intermediate inputs is the weighted average of price indices. Table 1 gives the definition and description of the data source for variables used in this study.

Data on the knowledge component is composed of government spending on agricultural education, agricultural research and agricultural extension. The data is taken from Shih, Fu and Chen (1990). Early studies such as Tang (1963) and Lin (1976) both calculate agricultural education spending by multiplying national education spending with the proportion of agricultural employment in the total employment for the same calendar year. However, statistics indicate that the majority of the farmers (about 90%) are elementary and middle school graduates. Using national education spending as a base will clearly yield an overestimate of government’s education spending on the aggregate agriculture sector. Therefore, Shih, Fu and Chen use national education spending for the elementary/middle school to calculate agricultural education spending.

Although agricultural research in Taiwan is conducted by agricultural experiment stations as well as other research institutions, the financial support for those research comes mostly from the Council of Agriculture (COA), National Science Council (NSC), Taiwan Sugar Corporation and Taiwan Fertilizer Corporation. Shih, Fu and Chen therefore establish the data for agricultural research by summing up the spending record of these different sources. As for agricultural extension, the Farmer's Credit Association (FCA) in Taiwan is the major source of financial support for providing and commercializing new technology in agriculture. Therefore, Shih, Fu and Chen's estimate is based on the annual extension spending reported by various local FCAs.

3.1 Econometric Specification

Empirical implementation of the integrated approach is accomplished through a two-stage process. The first stage involves applying the time-series technique to examine if the usual adoption of a time trend variable is an acceptable procedure (Machado, 1995). We follow the four branch decision tree testing procedure proposed by Clark and Youngblood (1992) to investigate the time-series properties of the data. The testing procedure is summarized by Mochado (1995) as:

Test 1: test for 2 versus 1 unit root

Let Δ be the difference operation. The Dickey-Fuller test involves testing for the significance of β_2 in $\Delta^2 X_t = \alpha_0 + \beta_2 \Delta X_{t-1}$. A non-significant estimate of β_2 $\Delta^2 X_t = \alpha_0 + \beta_2 \Delta X_{t-1}$ will indicate 2 unit roots. On the other hand, if the null hypothesis is rejected, then go to Test 2.

Test 2: test for 1 versus 0 unit root

To perform the Dickey-Fuller test for one versus zero unit root, test if estimate of β_1 in $\Delta^2 X_t = \alpha_0 + \beta_1 X_{t-1} + \beta_2 \Delta X_{t-1}$ is significant. If estimate of β_1 in the test is significant, then we can conclude that the data series is stationary. On the other hand, if the null hypothesis is not rejected, then go to Test 3.

Test 3: test for random walk versus random walk with drift

A traditional t test of significance of the constant term, r_0, in $\Delta X_t = r_0 + r_1 \Delta X_{t-1}$ will be performed. A nonsignificant estimate of r_0 indicates random walk. On the other hand, if the null hypothesis is rejected, then go to Test 4.

Test 4: test for random walk with drift versus linear time trend

Once a random-walk with drift is determined in the previous test, perform Q_3 test (Dickey and Fuller, 1981) for random walk with drift versus linear time trend. That is, test for the joint significance of estimates of λ_1 and λ_2 in $\Delta X_t = r_0 + \lambda_1 X_{t-1} + \lambda_2 t + r_1 \Delta X_{t-1}$.

Econometric estimation at the second stage follows the standard practice undertaken in the applied dynamic dual analyses. First of all, closed-form expressions for the unknown system of equations cannot be obtained without appropriate specification of the value function. Although Epstein (1981) demonstrates that a complete characterization of the dynamic production structure requires a third-order Taylor series approximation to the underlying value function, most past studies adopt a second-order expansion of the value function. For instance, the normalized quadratic form (Vasavada and Chambers, 1986; Lopze, 19; Vasavada and Ball, 19; Howeard and Shumway, 1989), the modified, generalized Leontief second-order Taylor series expansion (Vasavada and Chambers, 1982; Howard and Shumway, 1988, 1989; Luh and Stefanou, 1991, 1993, 1996; Luh, 1995), as well as the log quadratic (in prices) - quadratic (in quasi-fixed inputs) function (Taylor and Monson). Although these functional forms are not truly flexible, flexibility is achieved ~~rendered~~ simply by appending additional terms of parameters to the equations (Epstein). In addition, these specifications maintain $J_k(\cdot)$ is linear in c leading to a flexible accelerator.

In the present analysis, the value function is specified as a modified generalized Leontief function. In addition to the regularity properties of the value function, two additional assumptions are incorporated into the theoretical model in order to conform with the restrictions imposed by observed data. The first involves restricting the second derivative of the value function with respect to the initial capital stock, J_{kk}, to equal zero, which is the necessary condition for consistent aggregation for the intertemporal profit-maximizing firm (Blackorby and Schworm, 1982). The second assumption concerns the approximated discrete measure for the net investment. The approximated discrete measure for net investment is based on the difference between the current and lagged capital stock; i.e., $K(\tau)$ is approximated as $K_\tau - K_{\tau-1}$.

Let p represent the price of output. The (2×1) vector of stock of quasi-fixed inputs is K, and K_1 is the stock of capital input; K_2 is that of labor. The (2×1) vector, c, is the corresponding rental prices. X denotes the quantity of the only variable input, intermediate input, and w is its corresponding price. Also, the knowledge component at the beginning of the period is denoted by z. The modified generalized Leontief value function with one output (Y), one variable input (X_1), and two quasi-fixed inputs (k_1,k_2) is of the following form:

$$J(p,w,c,k,z)=\begin{bmatrix} p & w\end{bmatrix}\begin{bmatrix} A_{pk} \\ A_{wk}\end{bmatrix}k+c'Bk+\begin{bmatrix} p^{1/2} & w^{1/2}\end{bmatrix}\begin{bmatrix} A_{pc} \\ A_{wc}\end{bmatrix}c^{1/2}+c^{1/2\prime}Fc^{1/2}$$
$$+\begin{bmatrix} p^{1/2} & w^{1/2}\end{bmatrix}\begin{bmatrix} A_{pp}A_{pw} \\ A_{wp}A_{ww}\end{bmatrix}\begin{bmatrix} p^{1/2} \\ w^{1/2}\end{bmatrix}+\begin{bmatrix} p & w & c'\end{bmatrix}\begin{bmatrix} A_{pz} \\ A_{wz} \\ A_{cz}\end{bmatrix}z, \qquad (7)$$

where F is symmetric and

$B^{-1}=\lfloor A_{ij}\rfloor_{2\times2}$, $A_{pp}=\lfloor H_{\rho\rho}\rfloor_{1\times1}$, $A_{wk}=\lfloor D_j\rfloor_{1\times2}$, $A_{pw}=\lfloor I_{\rho\rho}\rfloor_{1\times1}$, $A_{pc}=\lfloor E_j\rfloor_{1\times2}$,
$A_{ww}=\lfloor J_{\rho\rho}\rfloor_{1\times1}$, $A_{pk}=\lfloor B_j\rfloor_{1\times2}$, $F=\lfloor G_{ij}\rfloor_{2\times2}$, $A_{wc}=\lfloor F_j\rfloor_{1\times2}$, $A_{pz}=\lfloor N_1\rfloor_{1\times1}$,
$A_{wz}=\lfloor N_2\rfloor_{1\times1}$, $A_{cz}=\lfloor N_{3j}\rfloor_{1\times2}$.

The dynamic factor demand and output supply equations reflecting the importance of accumulated knowledge stock on decision making are derived by making use of equations (4a)-(4c).

$$\dot{K}_i^* = (r+A_{ii})k_i + A_{ij}k_j + \frac{r}{2}\sum_j^2 A_{ij}\left[E_j\left(\frac{p}{c_j}\right)^{1/2}+F_j\left(\frac{w}{c_j}\right)^{1/2}+2\sum_\alpha^2 G_j\left(\frac{c_\alpha}{c_j}\right)^{1/2}\right]+rz\left(\sum A_{ij}N_{3j}\right), \quad (8a)$$

$$X^* = -\frac{r}{2}\left[\sum_j^2 F_j\left(\frac{c_j}{w}\right)^{1/2}+2I_{\rho\rho}\left(\frac{p}{w}\right)^{1/2}+2J_{\rho\rho}\right]+\sum_j^2 D_j(\dot{K}_j^*-rk_j)-N_2rz \qquad (8b)$$

$$Y_i^* = \frac{r}{2}\left[\sum_j^2 E_j\left(\frac{c_j}{p}\right)^{1/2}+2H_{\rho\rho}+2I_{\rho\rho}\left(\frac{w}{p}\right)^{1/2}\right]+\sum_j^2 B_j(rk_j-\dot{K}_j^*)-N_1rz. \qquad (8c)$$

The optimal net investment demand equations are consistent with the multivariate flexible accelerator model, thus can be rewritten as

$$\dot{K}^* = \begin{bmatrix} r + A_{11} & A_{12} \\ A_{21} & r + A_{22} \end{bmatrix} (K - \bar{K}^*),$$

where $\bar{K}^*$ is the vector of desired or long-run equilibrium levels of quasi-fixed factors. The long-run demand equations for the quasi-fixed inputs are solved by setting $\dot{K}^*$ equal to zero yielding

$$\bar{K}^* = -\begin{bmatrix} r + A_{11} & A_{12} \\ A_{21} & r + A_{22} \end{bmatrix}^{-1} \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \cdot \begin{bmatrix} \frac{r}{2}\left(E_1 \left(\frac{p}{c_1}\right)^{1/2} + F_1 \left(\frac{w}{c_1}\right)^{1/2} + 2\sum_{\alpha=1}^{2} G_{\alpha 1} \left(\frac{c_\alpha}{c_1}\right)^{1/2} \right) + M_{31}(rt-1) + zN_{31} \\ \frac{r}{2}\left(E_2 \left(\frac{p}{c_2}\right)^{1/2} + F_2 \left(\frac{w}{c_2}\right)^{1/2} + 2\sum_{\alpha=1}^{2} G_{\alpha 2} \left(\frac{c_\alpha}{c_2}\right)^{1/2} \right) + M_{32}(rt-1) + zN_{32} \end{bmatrix}$$

3.2 Empirical Results

Table 1 presents the unit-root tests on input indices, relative factor prices, output, and accumulated knowledge capital. Examining the time series properties of the input quantitites suggest capital and intermediate inputs both have a unit root with drift, while labor bias appear to follow a stationary process. These results suggest two out of the three variables has the unit root property. The time-series properties of the factor prices exhibit a somewhat different pattern. Although labor price can be adequately represented by a unit root with drift, there is a strong evidence of stationarity for capital price, and price of the intermediate input is the only variable exhibited trend stationarity. Finally, the two quantity variables-output and knowledge stock, both have a unit root with a drift.

The summary of test results in Table 3 suggest that for labor and capital, the factor biases and their corresponding factor prices are not of the same order, which accordingly implies that factor biases and factor prices are not cointegrated for these two inputs. As for the material input, because the factor bias and factor price both contain unit root, we proceed to test for cointegration. Table 4 reports the results of Engle-Granger cointegration tests. The results indicate that cointegration cannot be reject for the intermediate input. Therefore, the hypothesis that technical change tends to save the factors that become relatively more expensive only applies to the intermediate input.

Table 2 presents the asymptotically efficient parameter estimates and the corresponding approximate standard errors from the ITSUR estimation. The estimated rates of adjustment indicate both capital and labor adjust sluggishly toward their desired levels in response to relative price changes. Specifically, the rate of adjustment of physical capital is –0.354, implying it takes nearly three years for capital to adjust to its long-run equilibrium level. With an estimated adjustment rate –0.358, labor adjusts at a speed similar to that of capital.

Across-equation restrictions were imposed on the model to test the validity of the application of the dynamic dual model to the agricultural sector in Taiwan. The set of restrictions and the corresponding chi-square statistics are reported in Table 3. The first hypothesis concerns the independence of adjustment between quasi-fixed inputs. This null hypothesis has a test statistic 16.5178, suggesting rejection of the null hypothesis of independent adjustment. This result implies that the way in which capital adjusts towards its long-run equilibrium level, in response to relative price variation, depends on the degree of disequilibrium in labor and vice versa. The teat of sluggish adjustment involves confronting two sets of related but not nested tests with observed data. One hypothesis is to test for the presence of instantaneous adjustment. Imposing this restriction yields a chi-square test statistic 403.1354, with 4 degrees of freedom, this indicating that quasi-fixity is one characteristic of Taiwan's agricultural production. The other hypothesis is to determine whether individual quasi-fixed input is in fact freely variable by testing the magnitude of each of the diagonal elements in the adjustment matrix. Both hypothesis of instantaneous adjustment in capital and labor are soundly rejected, indicating that both inputs adjust slowly in response to variations of prices.

Table 4 presents the total scale measures both in the short run and long run. Descriptive statistics of the elasticities are also presented. Based on the Marshallian framework, Morrison and Berndt defined the short-run elasticities as those obtained when the quasi-fixed inputs are fixed, an intermediate-run as the time span allowing partial adjustment of stock variables, and long-run elasticities as the responses observed when quasi-fixed inputs have adjusted fully to their respective long-run equilibrium levels. We extend this concept in measuring the short- and long-run scale economies. Calculation of the total scale economies measures suggest Taiwan's production technology exhibit long-run increasing returns to scale in the presence of external economies. Comparison of the conventional measure of scale economies indicate a possible downward bias when short-run fixity as well as external economies from high-tech capital investment, R&E and human capital, are not explicitly recognized.

4. Concluding Remarks

This study proposes an integrated approach to measuring the broader definition of scale economies proposed by Morrison and Siegel. The paper attempts to tackle the three unsolved problems in Morrison and Siegel, and thus will offer a methodological refinement and in the meantime make a significant contribution to the literature.

Calculation of the total scale economies measures suggest Taiwan's production technology exhibit long-run increasing returns to scale in the presence of external economies. Comparison of the conventional measure of scale economies indicate a possible downward bias when short-run fixity as well as external economies from high-tech capital investment, R&E and human capital, are not explicitly recognized.

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Table 3 Dickey-Fuller Tests of Unit Root

	Test Statistics			
	Test 1	Test 2	Test 3	Test 4
Factor Biases				
Labor	-5.86*	-3.05*	–	–
Capital	-5.81*	-0.89	-1.49*	-1.52
Materials	-6.80*	1.77	-1.61*	-3.54
Factor Prices				
Labor	-4.20*	0.43	2.89*	2.70
Capital	-4.33*	-3.55*	–	–
Materials	-5.13*	0.51	-1.85*	6.21*
Quantity				
Output	-7.22*	-1.79	4.31*	1.83
Knowledge Capital	-5.86*	-0.58	3.01*	0.160
Critical Values (10% significance level)	-2.62	-2.62	1.31	5.81

A "*" denotes significance at the 10% level.

	Summary of Test Results
Factor Biases	
Labor	Stationary
Capital	Random walk with drift
Materials	Random walk with drift
Factor Prices	
Labor	Random with drift
Capital	Stationary
Materials	Trend stationary
Quantity	
Output	Random walk with drift
Knowledge Capital	Random walk with drift

Table 2: Coefficient Estimates of the Full Model

Parameter	Estimate*	Approximate Standard Errors
A_{11}	0.403786	0.12060
A_{22}	0.407510	0.10617
A_{12}	0.089664	0.03983
A_{21}	0.983219	0.28838
E_1	177.9771	242.539
E_2	-58.6463	82.5355
F_1	556.0184	520.868
F_{22}	440.5788	466.967
G_{11}	904.4697	3520.60
G_{12}	173.2413	12635.0
G_{22}	-5651.40	8986.60
G_{21}	603.7439	393.574
M_{21}	46.34652	17.3879
M_{31}	-3.15291	15.4096
M_{32}	27.30218	53.5791
$I_{\rho\rho}$	-11.4777	36.7830
$J_{\rho\rho}$	-259.859	2418.00
D_1	-9.00838	15.2940
D_2	3.899983	5.90965

* Adjusted R-square for $\dot{K}_i$ equation is 0.5336, for $\dot{K}_2$ equation is 0.7349. Adjusted R-square for X equation is 0.9752.

Table 3: Hypothesis Testing of the Full Model

Hypothesis	Test Statistics	Critical Values (Significance level 5%)
Univariate Flexible Accelerator (or Independence Adjustment)	16.5178	$\chi^2(2) = 5.9915$
All Factors Adjust Instantaneously	403.1354	$\chi^2(4) = 9.4877$
Capital Adjusts Instantaneously	178.3332	$\chi^2(3) = 7.8147$
Labor Adjusts Instantaneously	222.9831	$\chi^2(3) = 7.8147$

Table 4: Estimates of the Inter- and Long-Run Elasticities

Year	ε^{L-R}	ε^{S-R}
1953	0.60580	0.21658
1954	0.60685	0.21695
1955	0.59690	0.21340
1956	0.62034	0.22178
1957	0.63832	0.22820
1958	0.65330	0.23356
1959	0.64870	0.23192
1960	0.64888	0.23198
1961	0.66746	0.23862
1962	0.67064	0.23976
1963	0.66301	0.23703
1964	0.70294	0.25131
1965	0.73148	0.26151
1966	0.74496	0.26633
1967	0.77009	0.27531
1968	0.79483	0.28416
1969	0.77857	0.27835
1970	0.79806	0.28532
1971	0.81746	0.29225
1972	0.84126	0.30076
1973	0.87858	0.31410
1974	0.90875	0.32489
1975	0.86651	0.30978
1976	0.94482	0.33778
1977	0.97837	0.34978
1978	0.98829	0.35332
1979	1.02856	0.36772
1980	1.14761	0.41028
1981	1.26345	0.45170
1982	1.31009	0.46837
1983	1.29450	0.46280
1984	1.25912	0.45015

Table 4: Estimates of the Inter- and Long-Run Elasticities (Continued)

Year	ε^{L-R}	ε^{S-R}
1985	1.28635	0.45988
1986	1.29053	0.46138
1987	1.28469	0.45929

Descriptive statistics:

Variable	N	Mean	Std Dev	Minimum	Maximum
ε^{L}_{LQ}	35	0.8780016	0.2442704	0.5969050	1.3100879
ε^{I}_{LQ}	35	0.3138944	0.0873291	0.2133995	0.4683695